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ORIGINAL RESEARCH

Drinking pattern and blood pressure among non-hypertensive current drinkers: findings from 1999–2004 National Health and Nutrition Examination Survey

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Context and objective: Epidemiological studies show the apparent link between excessive alcohol consumption and hypertension. However, the association between alcohol intake and blood pressure among non-hypertensive individuals is scarcely examined.

Methods: This analysis included participants in the 1999–2004 National Health and Nutrition Examination Survey who were aged 20 to 84 years without a diagnosis of cardiovascular disease, hypertension or pregnancy, whose systolic/diastolic blood pressure (SBP/DBP) was lower than 140/90 mmHg, who were not on antihypertensive medication, and who consumed 12 drinks or more during the past 12 months (N = 3957). Average drinking volume (average alcohol intake per day), usual drinking quantity (drinks per day when drinking) and frequency of binge drinking were used to predict SBP/DBP. Covariates included age, gender, race/ethnicity, education level, smoking status, average physical activity level, and daily hours spent on TV/video/computer.

Results: Drinking volume was directly associated with higher SBP in a linear dependent manner (an increment of 10 g of alcohol per day increased average SBP by 1 mmHg among both men and women). Drinking above the US Dietary Guidelines (men more than two drinks and women more than one drink per drinking day) was associated with higher SBP. Binge drinking was associated with both higher SBP and higher DBP. Average intake greater than two drinks per day was particularly associated with higher DBP among women ($P = 0.0003$).

Conclusion: This analysis from a population-based survey indicates a direct association between higher alcohol consumption and a higher prevalence of prehypertension among non-hypertensive drinkers.

Keywords: blood pressure, drinking, ethanol, life style, prehypertension

Introduction

It is well established that excessive alcohol consumption is associated with elevated blood pressure. However, low to moderate levels of drinking are common among drinkers who have not yet developed hypertension. Whether or not low to moderate levels of drinking are associated with elevated blood pressure is controversial. Some population cohort[1–4] and cross-sectional studies[5–8] reported a positive association between levels of alcohol consumption and blood pressure, even from the lowest levels of consumption.[9–12] Other studies revealed a J-shaped or U-shaped alcohol-blood pressure association.[13–15] Gender-differential associations were also reported.[16] However, the controversial results in the association of blood pressure with low levels of consumption may be related to methodological approaches. For example, in almost

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all such studies, non-drinkers were used as the reference group. This may not be appropriate because non-drinkers are a heterogeneous group consisting of former drinkers, lifelong abstainers and irregular abstainers who may have preexisting health problems. Furthermore, whether drinking patterns play a role in hypertensive risk has not been investigated in depth.

The present study aimed to examine the association of drinking patterns with blood pressure among non-hypertensive current drinkers. By restricting study populations to non-hypertensive drinkers, we attempted to establish the association of low to moderate levels of alcohol consumption with blood pressure. We also aimed to examine whether the associations are different between men and women.

Materials and methods

Data source

Data were obtained from the 1999–2004 National Health and Nutrition Examination Survey (NHANES), a population-based survey of the non-institutionalized US population. NHANES includes both an interview and a physical examination. We restricted our analysis to current drinkers (participants who consumed 12 or more alcoholic drinks during the past 12 months) aged 20 to 84 years, and who fasted at least 8 hours before the blood draw. We excluded those who had been diagnosed as having high blood pressure; whose actual measurements of blood pressure exceeded 140/90 mmHg; who were on antihypertensive medication; who had had a diagnosis of cardiovascular disease (angina/heart attack/coronary heart disease, heart failure, stroke), who were pregnant; who had reduced their consumption of alcohol following a doctor's advice. This last exclusion was made to ensure that drinking habits had not changed because of health conditions relevant to the study outcome. This yielded 3957 participants with complete data for both blood pressure and alcohol consumption. Full details of the NHANES 1999–2004 design are available online.[17]

Measures

Alcohol consumption patterns

Measures of current drinking patterns included frequency, usual quantity, drinking exceeding the US Dietary Guidelines, and frequency of binge drinking. Frequency was assessed by asking "In the past 12 months, how often did you drink any alcoholic beverages?" We grouped responses into 3 categories (<1 day per week, 1–2 days per week, ≥3 days per week). Usual quantity was assessed by the question "On those days when you drank alcoholic beverages, on the average, how many drinks did you have?" We grouped responses into 3 categories (1, 2, and ≥3 drinks per day when drinking). Men who consumed >2 drinks/day (ie, who usually drank 3 or more per day when drinking) and women who consumed >1 drink/day (ie, who usually drank 2 or more per day when drinking) were classified as drinking in excess of the US Dietary Guidelines[18] and were defined as drinking exceeding the Guideline. Frequency of binge drinking was assessed by asking about the "number of days you had five or more drinks in the past 12 months." We grouped responses into 3 categories (no binge drinking, <once per week, and ≥once per week). Those who reported binge drinking ≥once per week were defined as frequent binge drinkers.[19]

Measurement of blood pressure and definition of prehypertension

Average SBP and DBP were obtained according to the analytic protocol http://www.cdc.gov/nchs/nhanes/nhanes2001-2002/BPX_B.htm. Briefly, if only one blood pressure reading was obtained, that reading was the average. If there was more than one blood pressure reading, the first reading was always excluded from the average. If only two blood pressure readings were obtained, the second blood pressure reading was the average. Prehypertension is defined as an average systolic pressure of 120 to 139 mmHg or an average diastolic pressure of 80 to 89 mmHg.

Covariates and potential confounders

Demographic variables (age, gender, race/ethnicity, years of education), family medical history (heart attack, stroke, diabetes, hypertension), dietary practice (gender-specific quartiles of saturated fat intake and of dietary fiber intake), video-based physical inactivity (daily hours of TV, video, or computer use outside of work), habitual daily activity level (sedentary, light, some moderate-to-vigorous activity), and tobacco use (never, former, and current smoker) were considered as covariates in the regression models. We included both habitual physical activity level and hours per day spent on computer, video or TV because they represent different dimensions of physical activity and both were significant in the regression model.

Statistical analysis

The analysis was performed using SAS-callable SUDAAN 10.0 (Research Triangle Institute, Research Triangle

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Park, NC) to account for the complex sampling design of the NHANES. Average systolic and diastolic blood pressures were used as dependent variables in multiple regression models. Separate analyses were carried out by gender. Least-square means (which can be interpreted as adjusted means) of blood pressures were obtained by drinking volume category. Model 1 was adjusted for age and race/ethnicity only. Model 2 was adjusted for age, race/ethnicity, education attainment, BMI category, smoking status, usual physical activity level, and hours per day spent on computer, video or TV. We then tested the association of blood pressures with different drinking pattern variables including: drinks per day when drinking; drinking exceeding the US Dietary Guidelines; drinking frequency; and frequency of binge drinking. A linear trend test was carried out to detect whether blood pressure measures varied across different categories of the drinking pattern measures. Finally, we used log linear regression analyses to obtain multivariate-adjusted prevalence ratios (PRs) for prehypertension by drinking pattern variables. *P*-values were 2-sided, with $P < 0.05$ considered significant.

Results

A total of 3957 eligible current drinkers were included in the analysis from NHANES 1999–2004. Overall, male drinkers (n = 2456) had a higher average systolic blood pressure (117.7 versus 111.8 mmHg) and diastolic blood pressure (71.7 versus 69.4 mmHg) than female drinkers (n = 1501). A large proportion of the non-hypertensive current drinkers had prehypertension [52% (95% CI: 49%–55%) among males and 29% (95% CI: 26%–32%) among females]. Male current drinkers consumed more drinks in terms of volume, quantity and frequency than female drinkers. Male drinkers also had more episodes of binge drinking than female drinkers. However, more female drinkers exceeded the US Dietary Guidelines (greater than one drink per day when drinking) compared to male drinkers (greater than two drinks per day when drinking) (Table 1).

Drinking volume was associated with higher SBP in a linear dependent manner (an increment of 10 g of alcohol per day was associated with an increase of SBP by 1 mmHg on average) among both men and women (Table 2). There was a differential volume-BP association between men and women. DBP increased linearly with drinking volume among women, while there was no statistical difference of DBP at different levels of drinking volume among men.

Both SBP (*P* for linear trend = 0.001) and DBP (*P* for linear trend = 0.03) increased with increasing alcohol quantity among male drinkers (Table 3). Drinking exceeding the Guidelines was associated with higher SBP among male drinkers ($P = 0.002$). These associations were not significant among females.

Table 1 Characteristics of eligible current drinkers by gender (n = 3957)

Characteristic	Men (n = 2456)	Women (n = 1501)	*P* for difference*
Continuous variables, mean (SE)			
Age in years	38.4 (0.4)	38.9 (0.3)	0.33
Systolic blood pressure (mmHg)	117.7 (0.4)	111.8 (0.4)	<0.001
Diastolic blood pressure (mmHg)	71.7 (0.2)	69.4 (0.3)	<0.001
Categorical variables, % (SE)			
Prehypertension (%)	51.9 (1.5)	28.8 (1.5)	<0.001
Race/ethnicity			<0.001
Non-Hispanic white	73.0 (1.7)	79.1 (1.8)	
Non-Hispanic black	7.7 (0.7)	7.2 (0.7)	
Mexican American	10.2 (1.0)	5.1 (0.7)	
Other	9.2 (1.5)	8.6 (1.4)	
Education			
Lower than high school graduate	17.2 (1.0)	10.5 (0.9)	
High school graduate	25.0 (1.2)	22.6 (1.4)	
More than high school	57.9 (1.5)	66.9 (1.7)	
Volume (drinks during the past 30 days)			<0.001
1–9	40.7 (1.0)	62.3 (1.6)	
10–29	26.3 (1.0)	22.6 (1.4)	
30–59	16.0 (0.7)	9.8 (0.9)	
≥60	17.0 (0.7)	5.3 (0.7)	
Quantity (drinks per day when drinking)			<0.001
1	17.5 (1.2)	28.4 (1.6)	
2	27.9 (1.2)	36.7 (1.5)	
≥3	54.6 (1.7)	34.8 (1.7)	
Drinking exceeding the US Dietary Guidelines			<0.001
No	45.4 (1.7)	28.4 (1.6)	
Yes	54.6 (1.7)	71.6 (1.6)	
Frequency (drinking days per week)			<0.001
<1	34.4 (1.1)	49.4 (1.7)	
1–2	36.6 (1.4)	31.5 (1.3)	
≥3	29.1 (1.3)	19.1 (1.4)	
Frequency of binge drinking (times per week)			<0.001
0	34.8 (1.3)	61.5 (1.5)	
<1	45.9 (1.4)	32.9 (1.7)	
≥1	19.3 (1.0)	5.6 (0.7)	

Note: NHANES, 1999–2004. *P for difference was obtained from *t*-tests for continuous variables and Chi-square tests for categorical variables.
Abbreviations: NHANES, National Health and Nutrition Examination Survey; SE, standard error.

Table 2 Adjusted means (SEs) of systolic and diastolic blood pressure by gender and drinking volume category

	Drinks during the past 30 days				*P* for linear trend
	1–9	10–29	30–59	≥60	
Women, n	962	329	133	77	
SBP, mmHg					
Model 1*	114.6 (0.6)	116.1 (0.8)	118.1 (1.7)	119.9 (1.2)	<0.001
Model 2†	115.0 (0.8)	117.4 (1.3)	120.9 (3.0)	124.8 (2.1)	0.0018
DBP, mmHg					
Model 1	70.6 (0.3)	70.8 (0.5)	71.3 (1.2)	72.9 (0.9)	0.0083
Model 2	71.3 (0.5)	71.0 (0.7)	74.3 (2.5)	77.1 (1.0)	<0.001
Men, n	1039	643	377	397	
SBP, mmHg					
Model 1	120.0 (0.6)	120.7 (0.6)	122.1 (0.8)	123.4 (0.9)	<0.001
Model 2	118.9 (1.0)	120.2 (1.1)	121.9 (1.5)	123.1 (0.5)	<0.001
DBP, mmHg					
Model 1	73.3 (0.3)	73.5 (0.5)	74.1 (0.6)	74.1 (0.6)	0.19
Model 2	73.2 (0.6)	72.6 (0.7)	74.1 (1.0)	74.6 (0.8)	0.056

Notes: NHANES, 1999–2004. *Model 1 was adjusted for age and race/ethnicity; †model 2 was adjusted for age, race/ethnicity, education attainment, BMI category, smoking status, usual physical activity level, and hours per day spent on computer, video or TV.
Abbreviations: NHANES, National Health and Nutrition Examination Survey; SE, standard error; SBP, systolic blood pressure; DBP, diastolic blood pressure.

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Female drinkers who drank more frequently (more days per week) manifested higher SBP (*P* for linear trend = 0.009) and DBP (*P* for linear trend = 0.04) (Table 4). Male drinkers who drank more frequently manifested higher SBP (*P* for linear trend = 0.03). Higher frequency of binge drinking was associated with elevated SBP among men (*P* for linear trend = 0.005).

The association of drinking patterns with prehypertension by gender is shown in Table 5. Consuming more than 60 drinks during the past 30 days and drinking three days or more frequently per week was significantly associated with higher prevalence of prehypertension for male and female drinkers. Consuming 3 drinks or more per day when drinking, or drinking exceeding the Guidelines, or having one or more binge drinking episode per week was associated with higher prevalence of prehypertension only among male drinkers.

Discussion

This population-based study revealed a significant association between drinking patterns and blood pressure among non-hypertensive current drinkers. Total drinking volume is associated with SBP in a linear manner in both men and women, which indicates that alcohol consumption may be associated with prehypertension risk.

The alcohol-blood pressure associations appear to be different by gender. Higher drinking quantity and frequency of binge drinking were associated with higher blood pressure in men but not in women. This differential association may be related to the fact that male drinkers usually drank more frequently with a higher quantity and had more binge drinking episodes. Therefore, the adverse effects become more manifest in male drinkers. This can explain why a higher proportion of diagnosed high

Table 3 Adjusted means (SEs) of systolic and diastolic blood pressures by gender and drinking quantity category*

	Drinks per day when drinking			*P* for linear trend	Drinking exceeding the US Dietary Guidelines		*P* for difference
	1	2	≥3		No	Yes	
Women, n	433	522	546		433	1068	
SBP, mmHg	113.8 (1.4)	119.1 (1.9)	116.3 (1.4)	0.09	111.3 (1.1)	112.9 (1.0)	0.19
DBP, mmHg	70.6 (0.7)	73.3 (1.2)	71.2 (0.8)	0.09	69.4 (0.6)	70.1 (0.7)	0.50
Men, n	438	635	1383		1073	1383	
SBP, mmHg	118.6 (1.5)	118.9 (0.9)	122.1 (0.6)	<0.001	115.8 (0.7)	118.7 (0.5)	0.0017
DBP, mmHg	72.1 (0.9)	74.1 (0.8)	73.6 (0.5)	0.028	72.1 (0.7)	70.7 (0.6)	0.12

Notes: NHANES, 1999–2004. *The estimates were obtained after adjustment for age, race/ethnicity, educational attainment, BMI category, smoking status, usual physical activity level, and daily hours spent on computer, video or TV.
Abbreviations: NHANES, National Health and Nutrition Examination Survey; SE, standard error; SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 4 Adjusted means (SEs) of systolic and diastolic blood pressures by gender and drinking frequency category*

	Frequency			*P* for linear trend	Frequency of binge drinking			*P* for linear trend
	<1 day/week	1–2 days/week	≥3 days/week		None	<once/week	≥once/week	
Women, n	784	457	260		938	471	89	
SBP, mmHg	115.5 (0.8)	115.7 (1.4)	120.7 (1.9)	0.0089	116.2 (1.2)	117.6 (1.1)	117.8 (2.1)	0.51
DBP, mmHg	71.6 (0.6)	70.6 (0.6)	74.2 (1.5)	0.04	71.5 (0.8)	72.6 (0.9)	70.5 (2.6)	0.68
Men, n	908	889	659		901	1060	491	
SBP, mmHg	119.1 (0.9)	120.4 (0.8)	122.2 (1.0)	0.026	119.1 (1.1)	120.4 (1.0)	123.1 (0.8)	0.0053
DBP, mmHg	73.2 (0.6)	73.4 (0.6)	73.8 (0.9)	0.54	73.2 (0.9)	72.8 (0.7)	75.2 (0.8)	0.16

Notes: NHANES, 1999–2004. *The estimates were obtained after adjustment for age, race/ethnicity, education attainment, BMI category, smoking status, usual physical activity level, and hours per day spent on computer, video or TV.
Abbreviations: NHANES, National Health and Nutrition Examination Survey; SE, standard error; SBP, systolic blood pressure; DBP, diastolic blood pressure.

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blood pressure in men is attributable to alcohol consumption than in women.[20]

In previous studies, when non-drinkers were used as the reference group,[16] a J-shaped alcohol-hypertension association among women and a linear association among men was frequently reported. However, our results do not support the notion that "light-to-moderate alcohol consumption decreased hypertension risk in women and increased risk in men".[16] The use of non-drinkers as the referent groups has been problematic. When examining alcohol-blood pressure association among current drinkers, we observed that a threshold beyond which alcohol consumption begins to become harmful does not appear to exist.

Table 5 Multivariate-adjusted* prevalence ratios for prehypertension in association with drinking patterns†

	Men PR (95% CI)	Women PR (95% CI)
Volume (drinks during the past 30 days)		
1–9	1.00	1.00
10–29	1.21 (1.06–1.39)	1.12 (0.87–1.46)
30–59	1.23 (1.00–1.51)	1.22 (0.86–1.71)
≥60	1.34 (1.16–1.55)	1.78 (1.44–2.19)
Quantity (drinks per drinking day)		
1	1.00	1.00
2	1.20 (1.00–1.44)	1.15 (0.78–1.69)
≥3	1.33 (1.11–1.58)	1.01 (0.64–1.59)
Drinking exceeding the US Dietary Guidelines		
No	1.00	1.00
Yes	1.17 (1.06–1.30)	1.11 (0.77–1.59)
Frequency (drinking days per week)		
<1	1.00	1.00
1–2	1.18 (1.03–1.35)	0.97 (0.76–1.24)
≥3	1.26 (1.09–1.45)	1.33 (1.04–1.69)
Frequency of binge drinking (times per week)		
0	1.00	1.00
<1	1.05 (0.87–1.26)	1.00 (0.69–1.45)
≥1	1.26 (1.08–1.53)	1.49 (0.87–2.56)

Notes: NHANES, 1999–2004. *The estimates were prevalence ratios (95% CI) adjusted for age, race/ethnicity, educational attainment, BMI category, smoking status, usual physical activity level, and daily hours spent on computer, video or TV; †prehypertension is defined as systolic/diastolic blood pressure values of 120–139/80–89 mmHg.
Abbreviations: NHANES, National Health and Nutrition Examination Survey; PR, prevalence ratio.

Although only half of male current drinkers who were not hypertensive reported alcohol consumption that exceeded the Drinking Guidelines, about half of this population (52%) already manifested prehypertension. Data from 2005–2006 NHANES estimated that 1 out of 4 persons aged 20 years or older in US has prehypertension.[21] Some studies showed that alcohol consumption predicts prehypertension,[22] and progression from prehypertension to hypertension.[23–25] Randomized controlled trials show that reducing alcohol consumption lowers blood pressure in both non-hypertensive, and treated and untreated hypertensive subjects.[26–28] Xin et al reported a 76% reduction in alcohol consumption was associated with decreasing blood pressure, and this relationship is dose-dependent.[29] Questions remain as to whether the limit for sensible drinking (not to exceed two drinks on days when drinking) for males is really safe. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure actually recommended men of smaller body size to consume "no more than 0.5 oz of ethanol (one drink) per day".[30] In light of the risk of developing high blood pressure, it may be wise to advise all male drinkers to consume no more than one drink per day. However, it is still unclear whether an intervention to lower alcohol intake in moderate to heavy drinkers with above optimal to slightly elevated diastolic blood pressure could produce sustained reduction of blood pressure.[31]

In our study, drinking quantity, frequency of binge drinking, and drinking frequency were all related to the health outcome of our concern. In addition, risk and frequency of binge drinking increased with frequency of drinking.[32] Therefore, researchers have recommended that drinking patterns should be taken into account in making drinking guidelines. For example, the National Institute on Alcohol

Abuse and Alcoholism (NIAAA) Physicians' Guidelines incorporating both daily and weekly alcohol limits performed better in the prediction of a variety of alcohol-related outcomes than the US Dietary Guidelines.[33]

Our study revealed a dose dependent relationship between alcohol consumption and higher average blood pressure among non-hypertensives. In addition, the associations of drinking patterns with the prevalence of prehypertension were gender-related. Our findings added to the large body of evidence that alcohol consumption is harmful. Preventive counseling for alcohol use should be integrated in primary care. Limits for sensible drinking need to be revisited with more epidemiologic data using robust analytic methods. More intervention studies are needed to examine the extent of the reduction in alcohol intake to produce significant reduction in blood pressure levels among drinkers.

Disclosure

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention. The authors report no conflicts of interest in this work.

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